SPACE WEATHERING OF ORDINARY CHONDRITE PARENT BODIES, ITS IMPACT ON THE METHOD OF DISTINGUISHING H, L, AND LL TYPES, AND IMPLICATIONS FOR ITOKAWA SAMPLES RETURNED BY THE HAYABUSA MISSION. T. Hiroi[1], S. Sasaki[2], S. K. Noble[3], and C. M. Pieters[1], [1]Department of Geological Sciences, Brown University, Providence, Rhode Island 02912, USA, [2]RISE Project, National Astronomical Observatory of Japan, Oshu City, Iwate Pref., Japan, [3]Mail Code 691, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA.

Introduction: As the most abundance meteorites in our collections, ordinary chondrites potentially have very important implications on the origin and formation of our Solar System. In order to map the distribution of ordinary chondrite-like asteroids through remote sensing, the space weathering effects of ordinary chondrite parent bodies must be addressed through experiments and modeling. Of particular importance is the impact on distinguishing different types (H/L/LL) of ordinary chondrites. In addition, samples of asteroid Itokawa returned by the Hayabusa spacecraft may reveal the mechanism of space weathering on an LL-chondrite parent body. Results of space weathering simulations on ordinary chondrites and implications for Itokawa samples are presented here.

Experimental: Samples of three ordinary chondrites, Nulles (H6), Chateau Renard (L6), and Appley Bridge (LL6) were ground into powders of <125 µm in size and pressed into pellets of about 12 mm in diameter and 1 mm in thickness. Each pellet was irradiated with YAG laser (1.064 µm in wavelength) pulsed at about 7 nanoseconds in a vacuum chamber according to the method described in [1]. Bidirectional visible and near-infrared reflectance spectra of unirradiated and irradiated samples were measured at 0° incidence and 30° emergence angles using a diffuse reflectance spectrometer manufactured by Bunko Keiki located in Mizusawa Campus of National Observatory of Japan (NAOJ). Spectralon was used as the reference material, and corrections for the brightness and absorption bands of Spectralon were made.

A New Space Weathering Index: Newly defined here is a space weathering index which is an improvement over [2] which dealt with the same spectral feature. Shown in Fig. 1 are reflectance spectra of the Chateau Reneard pellet irradiated with pulse laser at different amounts of energy. The slope change at 0.55 µm, which is distinct in the untreated sample spectrum, gradually decreases as the sample becomes more space-weathered. The amount of the visible slope change in the scaled reflectance spectrum measured by the angle in degrees (denoted as A_v) is calculated as:

$$A_v = -57.29578 \times \cos^{-1}\left\{\frac{(\lambda_v-\lambda_b)(\lambda_w-\lambda_v)+(1-R_b/R_v)(R_w/R_v-1)}{\sqrt{(\lambda_v-\lambda_b)^2+(1-R_b/R_v)^2}\sqrt{(\lambda_w-\lambda_v)^2+(R_w/R_v-1)^2}}\right\}$$

where λ_i and R_i denote the wavelength and reflectance at wavelength i (b, v, w = 0.42, 0.55, 0.70 µm in this study). The values of this index for the three ordinary chondrite samples before and after various amounts of laser energies are plotted in Fig. 2. The A_v value has a positive correlation with cumulative laser energy and is most sensitive for small degrees of space weathering.

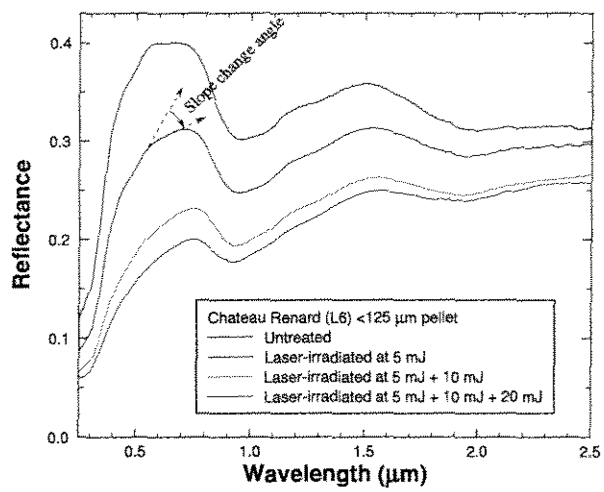

Fig. 1. Reflectance spectra of Chateau Renard sample irradiated with pulse laser, and an illustration of defining of the visible slope change as a new space weathering index.

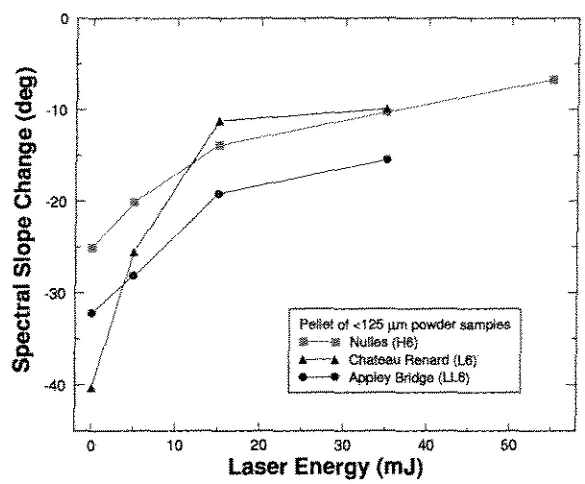

Fig. 2. Spectral slope change at 0.55 µm (A_v) of ordinary chondrite pellet samples irradiated with pulse laser at various amounts of cumulative energies.

Distinguishing Ordinary Chondrite Types: In order to remotely estimate the olivine/pyroxene ratio of an asteroid surface for detecting its meteorite counterpart, the ratio of silicate absorption bands around 1 and 2 μm in wavelength (Band II / Band I area ratio; BAR) is often used (e.g., [3]). Shown in Fig. 3 is a plot of BAR values of our three ordinary chondrite samples. Although the exact error bar size is not determined here, BAR values are not consistent over the range of 0 to 35 mJ in cumulative laser energy. This irregularity is caused mainly by the behavior of the 2-μm band strength, which is very weak and highly subject to the continuum removal method. This result suggests that it is difficult to distinguish L and LL chondrites with any space weathering based on their BAR values alone.

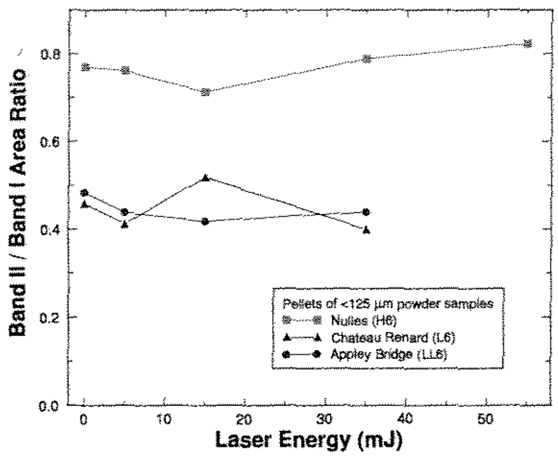

Fig. 3. Band II / Band I area ratios of ordinary chondrite samples plotted against cumulative laser energy applied.

On the other hand, there is another method of determining the ordinary chondrite type using only the 1-μm absorption band [4]. In this study, a small modification was made to the method of [4] in that the continuum of the 1 and 2 μm bands in the natural log reflectance spectrum was assumed to be linear to wavelength instead of wavenumber as in [4]. The result is plotted in Fig. 4. Both the band strengths at 1.05 μm and 1.25 μm relative to that at 0.95 μm decrease as the degree of space weathering increases. However, they move along a line connecting the three types of ordinary chondrites, and these H, L, and LL chondrite samples are well separated in this parameter space. This finding gives more credibility to the statistical result of [4] shown in Fig. 5, wherein LL chondrites are underrepresented. Asteroid Itokawa is also believed to have an LL-type composition [5, 6], and its samples returned by Hayabusa will probably shed light on this controversy (especially oxygen isotopic composition).

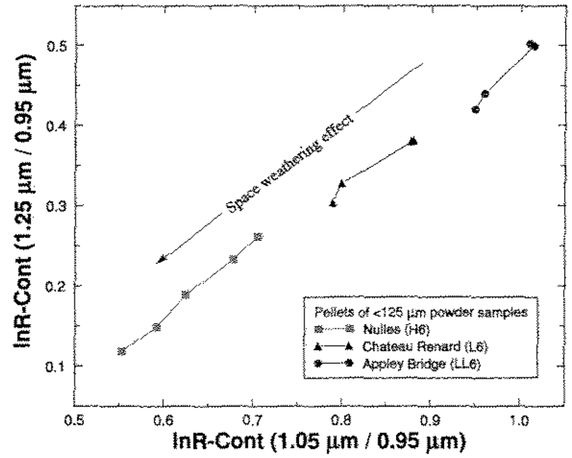

Fig. 4. Three band strength ratio plot [4] of three ordinary chondrite samples irradiated with pulse laser with various cumulative laser energies.

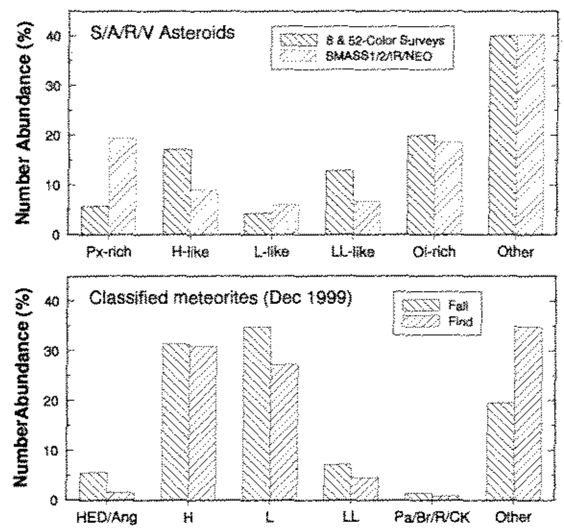

Fig. 5. Comparison of number abundances of S/A/R/V asteroids and meteorites of corresponding compositions [4].

Conclusions: The newly-introduced space weathering index is useful for ordinary chondrites. Three band strength ratio method utilizing the reflectance spectrum over the 1-μm band is less subject to space weathering than the common BAR method in estimating the olivine/pyroxene ratio of ordinary chondrites.

References: [1] Yamada M. et al. (1999) *EPS 51*, 1255-1265. [2] Hiroi T. et al. (2006) *LPS XXXVII*, Abstract #1396. [3] Gaffey M. J. et al. (1993) *Icarus 106*, 573. [4] Hiroi T. et al. (2008) *LPS XXXIX*, Abstract #1997. [5] Binzel R. P. et al. (2001) *Meteorit. & Planet. Sci. 36*, 1167. [6] Hiroi T. et al. (2006) *Nature 443*, 56.

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